

(U) Automated Statistical Analysis of Signal to Noise Ratio

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(U) Abstract: The Signal to Noise Ratio, (SNR), is a metric used to characterize image quality. In this paper we describe a method to calculate and characterize the signal to noise ratio for radiographic inspection using MATLAB®. The program is able to report SNR statistics for a given region of interest within a radiograph. Having an automated SNR search will aid radiographers assess image quality over a large number of radiographs. In addition to this, an SNR search tool, permits for a better characterization of image quality.

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(U) Research Innovation and Objective(s): For the purposes of radiographic inspection, SNR is measured across specified regions dictated by military specifications. Given an area on a radiograph, the program will output the maximum, minimum, mean and standard deviation of the SNR. The program will also produce a histogram and surface plot of SNR values. This will aid radiographers in assessing image quality and continue to push and develop industry standards.

(U) Impacts on Warfighter Mission: This program will continually improve internal processes. More importantly it will ensure delivery of the highest quality product to the warfighter.

(U) Keywords: Signal to Noise Ratio (SNR), Non-Destructive Testing (NDT), Radiograph, IQI, MATLAB®

1. (U) Introduction

(U) Radiographic testing is a non-destructive testing technique which allows for the detection of subsurface flaws. It is applicable to most materials and can reveal fabrication and underlying assembly errors. [1] An important metric to characterize image quality, is the signal to noise ratio. The program will output the minimum, maximum, mean and standard deviation of SNR over a region of interest. The program will also produce a histogram and surface plot of SNR values over the region.

2. (U) Method**2.1 (U) Theory**

(U) SNR is defined as the reciprocal of the coefficient of variation. That is, it is the ratio of the mean to the standard deviation of a signal.

$$SNR = \frac{\mu}{\sigma}$$

Here, μ is the signal mean and σ is the standard deviation of the noise. Consequently, in a gray scale radiograph, the SNR is a ratio of the mean grey value to the standard deviation of the pixel

values over a given neighborhood. According to ASTM 1316, Signal to Noise ratio is the quotient of the mean value of the linear pixel values and standard deviation of the mean linear pixel value (noise) I a given region of interest in a digital image. [2]

(U) The value of the signal to noise ratio is dependent on the radiation dose and the Digital Detector Array system properties. Qualitatively, the higher the SNR, the higher the image quality. However an SNR that is too large may indicate little to no attenuation. For 2% sensitivity applications, the SNR should be 130 or higher. It's important to note that not all conditions where a SNR of 130 is achieved will result in 2% contrast sensitivity. [3]

(U) For 1% sensitivity applications the SNR should be 250 or higher. Note that this is considered convention, as not all conditions where a SNR of 250:1 will result in 1% contrast sensitivity. [3]

(U) The minimum size of the rectangular region of interest for evaluation of SNR is 1100 pixels, 20 x 55 per ASTM 2737. [3]

(U) Per requirements, SNR should be measured in a homogenous area, near the IQI (image quality indicator). Many military specifications provide a picture of the item being inspected with detailed annotations where the SNR measurements should be taken.

(U) "Pixel hunting" is a colloquial term whereby radiographers form a 20x55 box per ASTM and "hunt" around till the requirement of 130 has been achieved. While this method can work, it is imprecise and less quantitative than one can achieve.

(U) Given the above, the radiographic laboratory wanted to have a quick way of measuring the maximum and minimum SNR for a given region in a radiograph. In addition to providing the maximum and minimum SNR, the program outputs a histogram of SNR values for the region of interest and a plot of the SNR as a function of the x and y coordinates.

2.1.1 (U) Program and Logic

(U) The image is read into MATLAB® using the function `dicomread`. This function converts the image to a matrix of pixel values. We then declare a submatrix defined by row and column numbers of the region of interest. As an example, we demonstrate using a radiograph of a M1 shell.



Figure 1. A radiograph of an M1 shell.

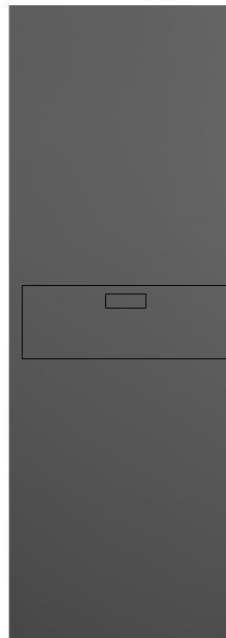


Figure 2. Two rectangles. One box defines the region of interest submatrix, the other shows the SNR box for which the SNR is a maximum.

(U) We then define an additional submatrix box, size 20x55 pixels. This smaller, SNR submatrix scans the region of interest submatrix in the following manner. The program moves the SNR box, pixel by pixel starting in the top left corner of the region of interest, scanning the entire row. After scanning the first row, the SNR box is moved to the second row. It then proceeds in a similar manner till the entire region of interest has been scanned.

(U) Each calculated value of SNR is stored in a matrix so that values can be retrieved and plotted. The maximum and minimum value are easily retrieved. A histogram like the one shown in figure 3 is produced. In addition to this, a surface plot is created of SNR vs. location. This is shown in figure 4 below.

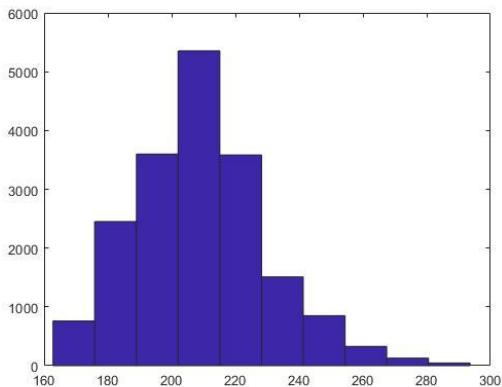


Figure 3. A Histogram of the SNR values calculated for the region of interest shown in figure 2.

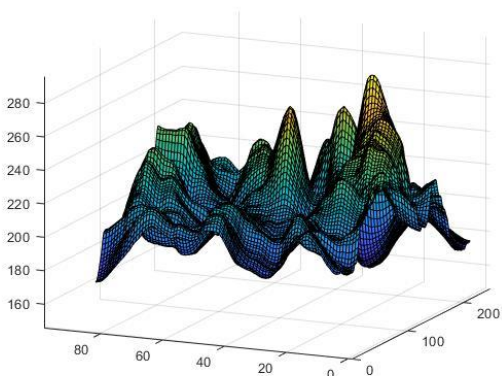


Figure 4. A Surface plot of SNR (z axis) as a function of position within the region of interest.

3. (U) Results and Discussion

(U) Results are in close agreement with those produced by Vi3 authored by VJ technologies. In the latest version of the VJ software, Vi3, an “SNR hunter” tool was made available to radiographers. It works in the following manner. A region of interest box is drawn directly on the radiograph being examined. One can then specify the size of an arbitrary box and the program will find the location and value of the largest SNR. One advantage of Vi3 is being able to draw the region of interest directly on the radiograph as opposed to specifying it numerically in MATLAB®.

(U) There are several key advantages of our implementation in MATLAB®. First, the run time is far faster in the MATLAB® implementation.

Second, our program allows for product to be examined in large quantities. Given a stack of radiographs of the same product, one can run this program through the image stack to check SNR requirements. Third, our program gathers statistics beyond maximum SNR. In fact, our program generates the following: maximum, minimum, mean and standard deviation. A histogram of SNR values is produced and a surface plot is created. Lastly, and most importantly, it removes the need for “pixel hunting”. More on this in the conclusion.

4. (U) Conclusion

(U) A program for calculating SNR metrics has been constructed using MATLAB®. Now that a reliable fast tool has been generated, one can examine the SNR in many radiographs within different regions of interest with ease. Image quality can be investigated and perhaps further refined using this tool.

4. (U) Appendix

The MATLAB® code is shown below so one can implement this program and or the principles therein.

```

cd 'C:\Users\'

X = dicomread('MC00AL7B_2.dcm');

L = 20; %length of snr box
w = 55; %width of snr box

%Submatrix Window
ymin = 920; %Starting row
ymax = 1020; %Ending row
xmin = 220; %Starting Column
xmax = 500; %Ending Column

W = X(ymin:ymax,xmin:xmax);
m = ymax-ymin+1; %Number of Pixels
in vertical direction
n = xmax-xmin+1; %Number of Pixels
in horizontal direction

snr = zeros(m-L+1,n-w+1);
%Initialize SNR Storage Matrix

%SNR Horizontal Orientation 20x55
for i = 1:m-L+1

    for j = 1:n-w+1
    
```

```

    Y = W(i:L-1+i, j:w-1+j);
%Border Inclusive

    mean = mean2(Y);

    std = std2(Y);

    snr(i,j) = mean/std;

    end

end

[a,b] = size(snr);

if a == 1

%Maximum SNR Location; Top Left
Corner of Box
    [snrmax, locmax] = max(snr);
%Minimum SNR Location; Top Left
Corner of Box
    [snrmin, locmin] = min(snr);

    y_max = ymin;
    x_max = locmax+xmin;
    y_min = ymin;
    x_min = locmin+xmin;

    figure(2)
    hist(snr(:))

elseif b==1

%Maximum SNR Location; Top Left
Corner of Box
    [snrmax, locmax] = max(snr);
%Minimum SNR Location; Top Left
Corner of Box
    [snrmin, locmin] = min(snr);

    y_max = locmax+ymin;
    x_max = xmin;
    y_min = locmin+ymin;
    x_min = xmin;

else

figure(1) %Surface Plot
surf(snr)

figure(2) %Histogram

    hist(snr(:))

    [snrmax,Idx] = max(snr(:));

    [snrmin,Idx_2] = min(snr(:));

%Maximum SNR Location; Top Left
Corner of Box
    [snrRowmax,snrColmax] =
ind2sub(size(snr), Idx);
    y_max = snrRowmax+ymin;
    x_max = snrColmax+xmin;

%Minimum SNR Location; Top Left
Corner of Box
    [snrRowmin,snrColmin] =
ind2sub(size(snr), Idx_2);
    y_min = snrRowmin+ymin;
    x_min = snrColmin+xmin;

figure (3) %Original Image
imshow(X);

figure (4) %Z contains the
submatrix and the SNR box
Z = X;
Z(ymin:ymax,xmin:xmin) = 0;
Z(ymin:ymax,xmax:xmax) = 0;
Z(ymin:ymin,xmin:xmax) = 0;
Z(ymax:ymax,xmin:xmax) = 0;

Z(y_max,x_max:x_max+w-1) = 0;
Z(y_max+L-1,x_max:x_max+w-1) = 0;
Z(y_max:y_max+L-1,x_max) = 0;
Z(y_max:y_max+L-1,x_max+w-1) = 0;

imshow(Z);

end

References

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3D-Printed Fixturing, DTIC Technical Reports,2019

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Nondestructive Examinations

3. ASTM E2597-07 Standard Practice for Manufacturing
Characterization of Digital Detector Arrays

4. ASTM E737-10 Standard Practice for Digital Detector
Array Performance for Evaluation and Long-Term
Stability

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